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A comprehensive analysis of strategies, policies and development of hydropower in India: Special emphasis on small hydro power

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A B S T R A C T

Many developing countries like India are facing energy crisis due to increase in industrialization for various development programs. If this increase in demand is supplied from coal based thermal power plants, it will cause environment pollution and high cost of generation. So the best solution is to develop hydropower and small hydro power (SHP) plants in the country. India is endowed with these resources which are both viable and economically exploitable. In fact, hydro power is the second highest contributor of the energy consumed in the Indian power sector. At the present time, it is the only clean energy source that can be commercially developed on a large as well as small scale. Recently, hydropower and SHP have considered as most readily available, renewable and clean sources of electricity. They use the potential energy of rivers and supply more than 20% of total India's electricity. SHP has also some advantages: They may be connected to conventional electrical distribution networks as a source of low-cost renewable energy. Alternatively, SHP projects may be built in isolated areas that would be uneconomic to serve from a network, or in areas where there is no national electrical distribution network so as to improve the quality of life. Therefore, this paper has been focused on the efforts to analyze the current status, future strategies and policies of hydropower development in India with special emphasis on SHP.

Contents

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1. Introduction

Energy is considered to be a key factor in the generation of wealth, social development and improved quality of life in all developed and developing countries in the world [1]. The global energy consumption is likely to grow faster than the population growth. Estimates of the world primary energy consumption are that 80% of the energy supply is provided by fossil fuels [2]. The Indian power sector is predominantly based on fossil fuels, with about three-fifths of the country's power generation capacity being dependent on vast indigenous reserves of coal. But in few last decades' Indian government has taken several steps to reduce the use of fossil fuels-based energy while promoting renewable generation [3,4].

Presently, India is moving from a vertically and horizontally integrated power industry towards an open market, multi-buyer multi-seller structure associated with an independent regulatory framework [5,6]. Regulatory framework led to setting up of State Electricity Regulatory Commissions (SERCs) and the Central Electricity Regulatory Commission (CERC) to promote competition, efficiency and economy in the activities of the electricity industry. The Electricity Act 2003 consolidates the laws relating to generation, transmission, distribution, trading and use of electricity. It also enabled competition in the Indian power sector in bulk as well as retail electricity supply. The power sector reform process in a number of states led to unbundling and corporatization of the erstwhile State Electricity Boards (SEBs), and privatization of distribution in the state of Orissa as well as other states [7–9].

Hydropower is playing an important role in Indian competitive power sector. It has been increasing significantly in recent years due to growing energy demand with minimum environmental impact. Hydropower can provide sustainable energy services, based on the use of routinely available, indigenous resources and provide best solutions to longstanding energy problems being faced by the country [3].

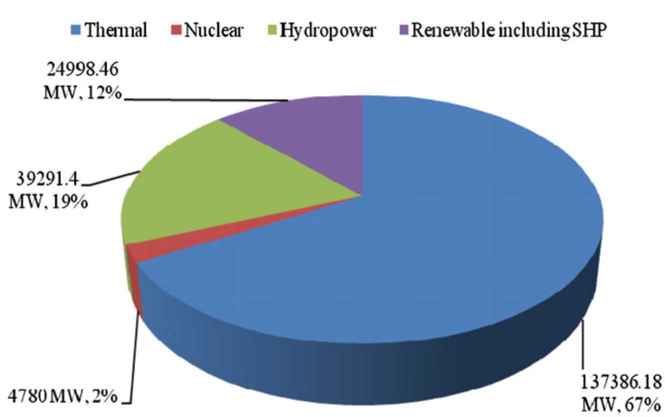

Fig. 1. Aggregate installed power capacities in India.
Source: MOP (2012).

Hydropower and small hydropower are the second highest contributors of the energy consumed in the Indian power which can immediately respond to fluctuations in electricity demand meeting both base-load and peak-load demands and therefore essential in order to stabilize the power grid [10,11]. They allow achieving self-sufficiency by using the best possible scarce natural resource that is the water, as a decentralized and low-cost of energy production [6]. The Indian hydropower and small hydropower rank sixth worldwide for total hydro capacity, with an existing capacity of more than 40 GW (including 39.2 GW of large-scale as on 31 August 2012), added about 0.3 GW of small-scale hydro in 2011 for a cumulative small hydropower capacity of 3.2 GW at year-end; another 1.1 GW of small hydropower were under construction as of early 2012 [10,11]. A capacity addition of more than 90,000 MW has been assessed during 12th plan (2012–2017), which includes 30,000 MW of hydro electric power [12].

This paper presents a comprehensive analysis of hydropower development in India with special emphasis on SHP in terms of availability, current status, major achievements, future strategies and promotion policies.

2. Current energy scenario in India

India is the 5th largest electricity generator, accounting for almost 4% of the global annual generation with a total installed capacity of 207,006 MW as of 31 August 2012 and by the 12th Plan (2012–2017), capacity addition close to 100,000 MW is anticipated, around 50% of which is expected to come from the private sector [10]. As illustrated in Fig. 1, around 67% of electricity generation is thermal based, 2% of generation is nuclear and 19% of electricity generation through large hydropower based, while the contribution from Renewable Energy Sources (RES) is about 12% of the total installed capacity in India [10].

Hence there is a large potential for renewable energy in India, an estimated aggregate of over 100,000 MW. India, total grid-connected renewable power generation capacity of 25,858.39 MW has been achieved till 31 August 2012, which is about 12% of the total installed power generating capacity in the country. It includes wind power of 17,967.2 MW, small hydropower of 3434.1 MW, biomass power of around 1209.6 MW, and around 1044.2 MW solar power as shown in Table 1 [11]. A grid connected capacity addition of 29,800 MW comprising 15,000 MW wind power, 10,000 MW solar power, 2100 MW small hydro power, and 2700 MW bio-power has been proposed during the 12th five year plan period that would take the renewable power generating capacity to nearly 55,000 MW by 2017 [11]. This momentum is likely to be sustained and it is envisaged that the renewable power capacity in the country will cross 87,000 MW by 2022.

2.1. Annual imported power by India

At present time India imports approx 5.3 Billion units (BU) energy from Bhutan. The power imported in last four financial years

Table 1
Grid-connected renewable power generation capacity in MW (as 31 August 2012).
Source: MNRE (2012).

Renewable energy program	Estimated potential	Target for 2012–2013	Total achievement during 2012–2013	Cumulative achievement up to 31.08.2012
Wind energy	49,000	2500	614.50	17,967.15
Small hydro power (SHP)	**15,000**	**350**	**38.76**	**3,434.07**
Biomass power	17,000	105	59.50	1,209.60
Bagasse cogeneration	5,000	350	124.50	2,109.73
Waste to power (Urban & Industrial)	3,900	20	4.00	93.68
Solar power	30–50 MW/km^2	800	102.88	1,044.16
Total	89,000 (excluding solar energy)	4125	944.14	25,858.39

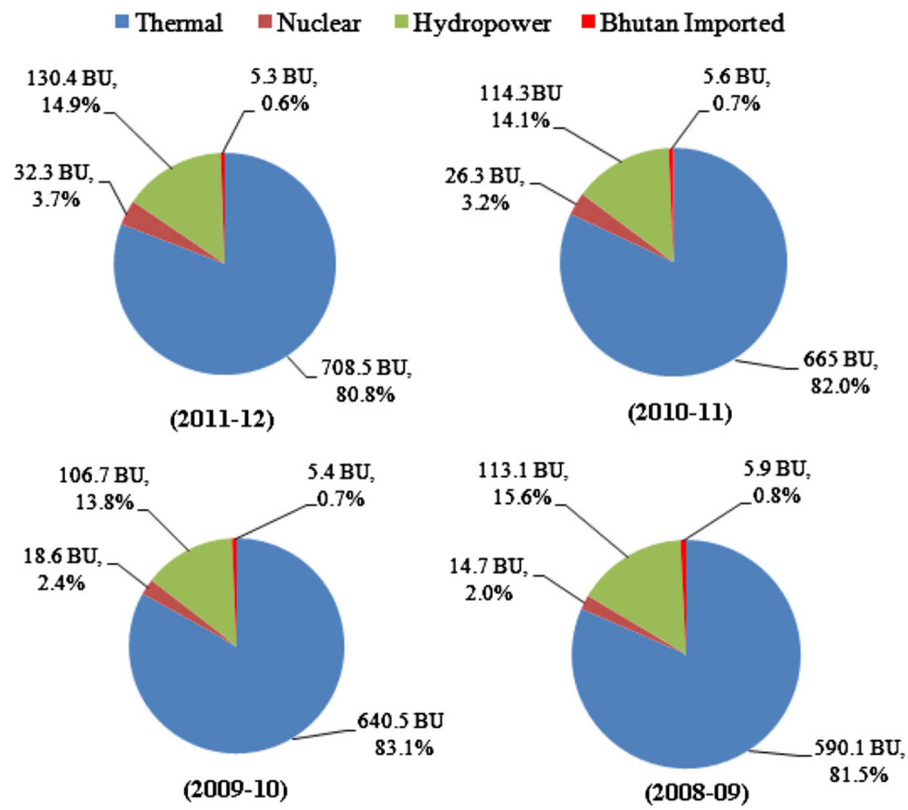

Fig. 2. Annual internal and import energy (Billion units) scenario in India.
Source: CEA (2008–2012).

(FY) is shown in Fig. 2 [13]. Due to geography and fast flowing rivers in Bhutan, there is huge hydropower potential estimated to be around 30,000 MW. At present about 1488 MW of this resource is tapped, from which about 75% of the electricity generated is exported to India [14,15]. India has a long association in providing technical and financial assistance to Bhutan in the development of its hydropower resources. Chukha hydropower project (336 MW) has been an important project developed as a joint venture between the Government of India and the Royal Government of Bhutan. About 84% of energy generated from Chukha plant is exported to India. The Kurichu hydroelectric project (60 MW) in eastern Bhutan has also been implemented with Indian financial and technical assistance. Further, the Governments of Bhutan and India are jointly planning to construct a total of ten Hydro Power Projects (HPPs), with an anticipated aggregate installed capacity of 11,576 MW, for development by 2020 [16–20].

India is also assisting the Nepal for development of its hydropower potential. Four hydroelectric schemes, namely Trisuli (21 MW), Western Gandhak (15 MW), Devighat (14.1) and Pokhra (1 MW) have been implemented in Nepal with financial and technical assistance from India [13]. The Trishuli was first hydropower plant under support from the Indian government [21]. The bilateral exchange of power at the borders between the India and Nepal is presently at a level of 50 MW. Nepal aims to develop 2230 MW of hydropower up to 2017 and planned to export 400 MW to India [22,23]. Thus, for the development of large hydroelectricity projects in Nepal, a good understanding between Nepal and India is crucial both to meet the financial requirement and to market the electricity [24,25].

2.2. Demand and supply power status in India

India's power sector is facing the electricity deficit and shortage. The widespread shortage of electricity supply is a basic obstacle to economic growth. The gap between demand and supply is expected to increase in future [26,27]. In the year 2011–2012, the total electricity demand in India was 937,199 million kW h, which was 8.06% more than the previous year (2010–2011). India was feeding 857,886 million kW h power in 2011–2012 which is 8.11% more than the year 2010–2011 [11]. Fig. 3 presents the gap between total energy demand and availability of last 10 years. The total peak demand (in FY 2011–2012) was also increased 1.15% than previous year's (2010–2011) peak demand. Therefore, energy deficit in 2011–2012 increased up to 10.6% due to poor availability of coal and its high international price. The southern and western regions were the worst affected in terms of power availability.

3. Hydropower in India

Hydropower is based on a simple process taking the advantage of the kinetic energy freed by the falling water. In all hydroelectric generating stations, the rushing water drives a turbine, which converts the water's motion into mechanical and electrical energy [12,16]. Hydroelectricity is clean energy and its generation is not linked to issues concerning fuel supply, especially the price volatility of imported fuels. It enhances our energy security and is ideal for meeting peak demand. It has higher efficiency (over 90%) compared to thermal (35%) and gas (around 50%) [24,25].

Hydropower projects are generally categorized in two segments i.e., small and large hydro. In India, hydro projects up to 25 MW station capacities have been categorized as SHP projects. While Ministry of Power (MOP), Government of India (GOI) is responsible for large hydro projects, the mandate for the subject small hydro power (up to 25 MW) is given to Ministry of New and Renewable Energy (MNRE) [13]. India's need for power is growing at a prodigious rate, annual electricity generation and consumption in

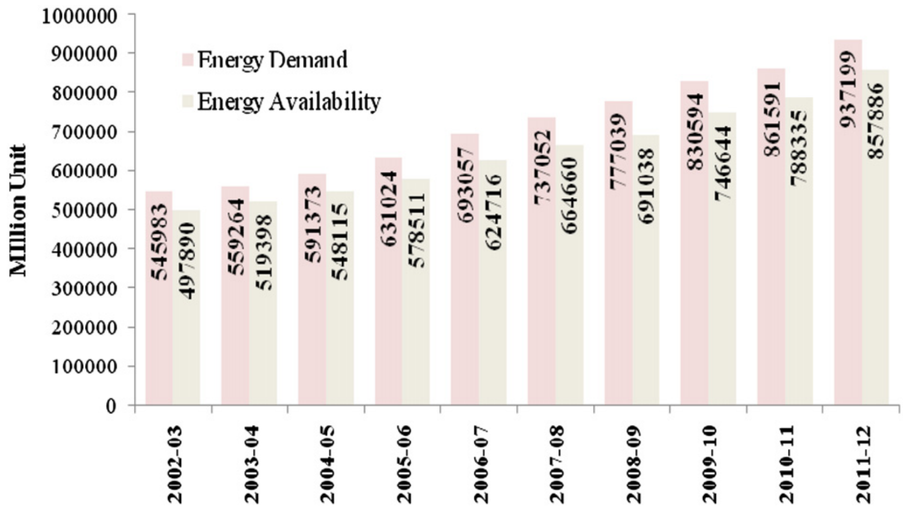

Fig. 3. Energy demand and availability status in India.
Source: CEA, MOP (2002–2012).

Table 2
Estimated basin-wise hydropower potential in India [12].

River basin	No. of schemes	Potential at 60% load factor	Probable installed capacity (MW)
Indus	190	19,988	33,382
Brahmaputra	226	10,715	66,065
Ganga	142	2,740	20,711
Central Indian river system	53	6,149	4,152
West flowing rivers of Southern India	94	9,532	94,300
East flowing rivers of Southern India	140	34,920	14,511
Total	**845**	**84,044**	**148,701**
Pumped storage schemes	56	–	94,000

India has increased by about 64% in the past decade. At the same time there is a need to provide energy access to rural areas and reduce import dependence on fossil fuels. India's approach is to meet its energy needs in a responsible, sustainable and eco-friendly manner [3].

At present 57% of electricity is generated through coal [10]. India's hydel resources are estimated to be 84,000 MW at 60% load factor [13]. The reassessment studies (1978–1987) of hydro electric potential were undertaken by Central Electricity Authority (CEA) for providing up-to-date data of hydro electric potential of the country and facilitate development of hydropower capacity. The estimated basin-wise hydropower potential in India is shown in Table 2. In addition, 56 numbers of sites exists for development of pumped storage schemes with likely aggregate installed capacity of about 94,000 MW were also identified in various regions of the country [13]. The share of hydro capacity in the total generating capacity of the country has declined from 34% at the end of the 6th plan to 25% at the end of the 9th plan. The plan wise growths of hydropower installed capacity as well as percentage share of total installed capacity are shown in Table 3 [12,13,28].

The functions of CEA are to advise the MOP on national power policy, national power planning and regulatory matters on the national level where as SERCs, does the same function at state level. Indian power sector is organized into five Regional Electricity Boards such as Northern Regional Electricity Board (NREB), Southern Regional Electricity Board (SREB), Western Regional Electricity Board (WREB), Eastern Regional Electricity Board (EREB) and North Eastern Regional Electricity Board (NEREB). Table 4 presents region wise installed capacity of hydropower along with total installed capacity. In this table, total numbers of hydropower stations with total number of units are shown. Fig. 4 shows the graphical representation of overall hydropower installed capacity versus total power installed capacity of each region as on 31 August 2012 [10,13].

The sector wise total installed hydropower capacity is shown in Fig. 5, whereas state wise estimated and developed capacity of hydropower is presented in Fig. 6 [13]. From Fig. 5, it is clear that state sector contributed more than 60% of total hydropower generation in India. Estimated and developed capacity of hydropower in Himachal Pradesh is largest among other states in India as clearly mentioned in Fig. 6.

4. SHP development in India

There is no international consensus on the definition of small hydropower (SHP). The general practice all over the world is to define SHP by power output. Different countries follow different norms keeping the upper limit ranging from 5 to 50 MW. In India, SHP schemes are classified by MNRE. The hydropower projects up to 25 MW capacities are classified as SHP [29–32].

SHP projects developments history in India is more than a century old; the first project of 130 kW was commissioned in the hills of Darjeeling, West Bengal in 1897. This project was followed by Sivasamudram project of 4.5 MW in Mysore district of Karnataka in 1902, which supplied power to Kolar gold mines. After that, two other plants were established: a 3 MW plant was established at Galgoi in Mussoorie in 1907 and a 1.75 MW plant was established at Chaba near Shimla in Himachal Pradesh in 1914. Some of these old SHP plants are reported to be still functioning properly [33–36].

MNRE has been vested with the responsibility of developing SHP projects. SHP is a very attractive renewable energy source because it uses mature and largely indigenous technology and its maximum power production is in the summer, which coincides with peak seasonal demand in India. The estimated potential for power generation in the country from such plants is over 15,000 MW [37]. It can make a significant contribution to India's power supply, especially in remote areas where alternative supply solutions face many challenges [38]. It is further subdivided into micro hydro (100 kW or less), mini hydro (between 100 and 2 MW), and small hydro (between 2 and 25 MW).

Table 3
The plan wise growth and share of hydropower installed capacity.
Source: CEA (2012).

Installed capacity at the end of plan (MW)				
Plan period	Hydro capacity addition during the plan (MW)	Hydro Power installed capacity	Total installed capacity including other R.E.S.	Hydro power share as % of total installed capacity
1st plan (1951–1956)	380.19	1,061.44	2,886.14	36.78
2nd plan (1956–1961)	977.18	1,916.66	4,653.05	41.19
3rd plan (1961–1966)	2,207.08	4,123.74	9,027.02	45.68
3 annual plans (1966–1969)	1,783.17	5,906.91	12,957.27	45.58
4th plan (1969–1974)	1,058.39	6,965.30	16,663.56	41.80
5th plan (1974–1979)	3,867.77	10,833.07	26,680.06	40.60
Annual plan (1979–1980)	550.90	11,383.97	28,447.83	40.01
6th plan (1980–1985)	3,076.05	14,460.02	42,584.72	33.96
7th plan (1985–1990)	3,828.41	18,307.63	63,636.34	28.77
2 annual plans (1990–1992)	881.50	19,194.62	69,065.19	27.79
8th plan (1992–1997)	2,427.65	21,658.8	85,795.37	25.46
9th plan (1997–1902)	4,538.25	26,261.23	103,410.04	25.40
10th Plan (2002–2007)	7,886.00	34,653.77	132,329.21	26.19
11th plan (2007–2012)	5,402.00	38,990.40	199,877.03	20.38
12th plan (2012–2017) (up to 31 August, 2012)	25,316.00	39,291.40	207,006.04	19.12

Table 4
Region wise total installed and hydropower capacity (MW) in India.
Source: CEA (2012).

S. No	Region	Hydropower			Total installed capacity
		No. of stations	No. of units	Installed capacity	
1.	NREB	60	202	15,479.25	56,089.15
2.	WREB	28	101	7,392.00	68,185.98
3.	SREB	66	239	11,372.45	53,361.95
4.	EREB	15	55	3,847.70	26,837.91
5.	NEREB	10	28	1,200.00	2,454.94
6.	Islands	0	0	0.00	76.12
All India		179	625	39,291.40	207,006.04

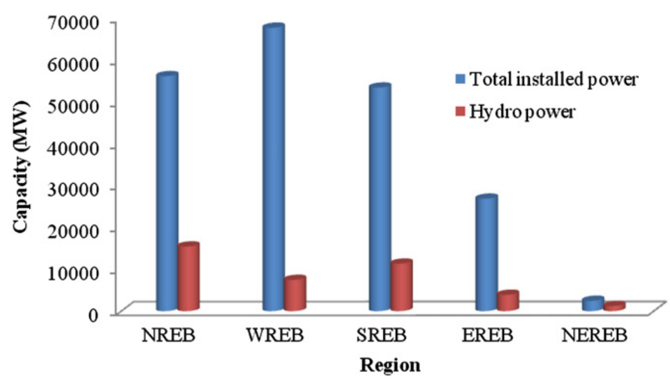

Fig. 4. Region wise installed hydropower in India.
Source: MOP (2012).

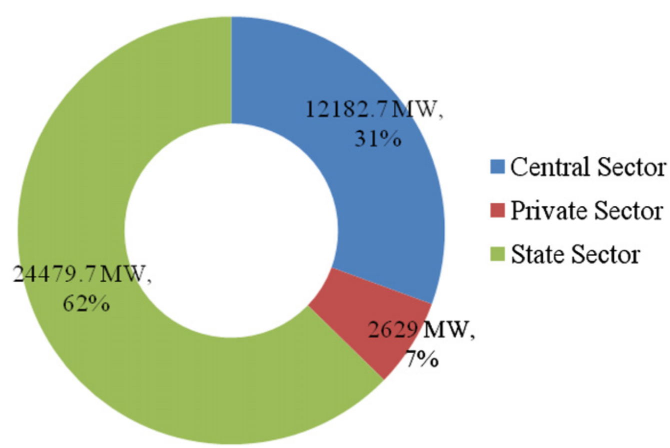

Fig. 5. Sector wise installed capacity of large hydropower.
Source: CEA (2012).

In India, 23 states have announced their policies to invite private sector to set up SHP projects [37].

India's installed SHP capacity of 3434 MW at the end of August 2012; it is contributing about 13.2% of total grid interactive renewable power generation [11]. Development of alternative energy has been part of India's strategy for expanding energy supply and meeting decentralized energy needs of the rural sector. The strategy is administered through MNRE, Energy development agencies in the various states and the Indian Renewable Energy Development Agency Limited (IREDA). These strategies is being achieved through research and development, demonstration projects, government subsidy programs, and also private sector projects and to promote the maximum utilization of all forms of SHP as well as to increase the share of renewable energy in the Indian power market.

MNRE has estimated the SHP potential for renewable power generation in the country from such plants 15,384 MW with 5718 prospective plant sites, which are shown in Table 5 [37]. Over 42% (6592 MW) of this total potential is shared by four northern mountainous states of India: Himachal Pradesh, Uttarakhand, Jammu and Kashmir, and Arunachal Pradesh [38]. Fig. 7 shows the year wise growth capacities of SHP in MW. From this figure it can be seen that cumulative growth capacity of SHP gets increases throughout the years and it is maximum in year 2011–2012. At the end of august 2012 it is 3434 MW, which achieved second place of renewable power generation after wind energy.

The Indian government aims to develop half of the identified potential in the next 10 years and is supporting small-hydro deployment through capital subsidies and preferential tariffs. India expects to bring 400 MW of pumped storage capacity on line by 2012. The detail of state wise estimated capacity of SHP projects from MNRE, GOI are shown in Table 5 along with estimated potential, number of sites, installed capacity, installed projects, and capacity under development as of December 31, 2011. The Ministry is providing financial support to the states for identification of new

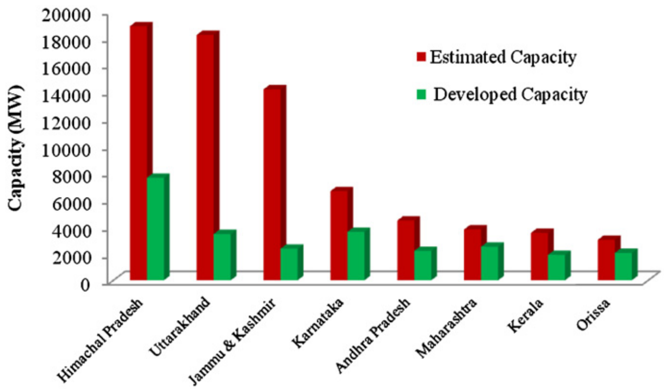

Fig. 6. Estimated and developed capacity in different states.
Source: CEA (2012).

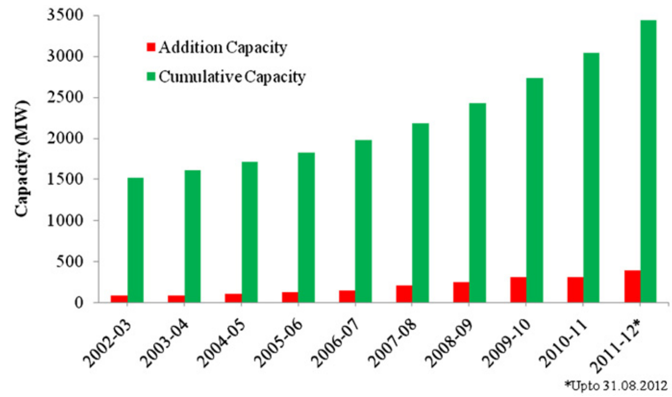

Fig. 7. Year wise growth for addition and cumulative capacity of SHP.
Source: MNRE (2012).

Table 5
State wise numbers and estimated capacity of SHP projects potential, installed and under implementation. (As on 31.12.2011) [37].
Source: MNRE (2012).

S. No	State	Estimated potential		Projects installed		Projects under implementation	
		Nos.	Capacity	Nos.	Capacity	Nos.	Capacity
1.	Andhra Pradesh	497	560.18	64	192.63	18	62.05
2.	Arunachal Pradesh	550	1328.68	104	79.54	117	46.97
3.	Assam	119	238.90	5	31.11	4	15.00
4.	Bihar	95	213.25	21	61.30	7	22.60
5.	Chhattisgarh	184	993.11	7	20.25	6	147.00
6.	Goa	6	6.50	1	0.05	–	–
7.	Gujarat	292	196.97	5	15.60	–	–
8.	Haryana	33	110.05	7	70.10	2	3.40
9.	Himachal Pradesh	536	2267.81	131	466.37	28	106.85
10.	J &K	246	1417.80	35	130.59	5	6.65
11.	Jharkhand	103	208.95	6	4.05	8	34.85
12.	Karnataka	138	747.59	126	871.75	13	126.18
13.	Kerala	245	704.10	21	141.67	13	60.75
14.	Madhya Pradesh	299	803.64	11	86.16	3	4.90
15.	Maharashtra	255	732.63	45	281.33	21	7.00
16.	Manipur	114	109.13	8	5.45	3	2.75
17.	Meghalaya	101	229.80	4	31.03	3	1.70
18.	Mizoram	75	166.93	18	36.47	1	0.50
19.	Nagaland	99	188.98	10	28.67	4	4.20
20.	Orissa	222	295.47	9	64.30	4	3.60
21.	Punjab	237	393.23	46	154.50	12	21.15
22.	Rajasthan	66	57.17	10	23.85	–	–
23.	Sikkim	91	265.55	17	52.11	1	0.20
24.	Tamil Nadu	197	659.51	20	111.69	–	18.00
25.	Tripura	13	46.86	3	16.01	–	–
26.	Uttar Pradesh	251	460.75	9	25.10	–	–
27.	Uttarakhand	444	1577.44	97	146.82	50	217.25
28.	West Bengal	203	396.11	23	98.40	17	84.25
29.	A&N Islands	7	7.27	1	5.25	–	–
Total		5718	15384.15	864	3252.13	340	997.80

potential sites and preparation of a perspective plan for the state for development of SHP [37,39]. The graphical representation of overall estimated, already installed and under implementation capacity of SHP under different states is shown in Fig. 8.

The GOI is encouraging the development of SHP projects and aims to double the current growth rate that leads to a capacity addition of 500 MW/year with total installed capacity of 4000 MW by the end of 2012. The GOI is also providing concessions for existing hydro projects including financial support for renovation, modernization and capacity upgrading of aging SHP stations [40].

In India, 261 private sector SHP projects of about 1326.68 MW capacities have been setup. The state-wise details as provided by MNRE are shown in Table 6. Private sector entrepreneurs are finding attractive business opportunities in small hydro and state governments also feels that the private participation may be necessary for tapping the full potential of rivers and canals for power generation.

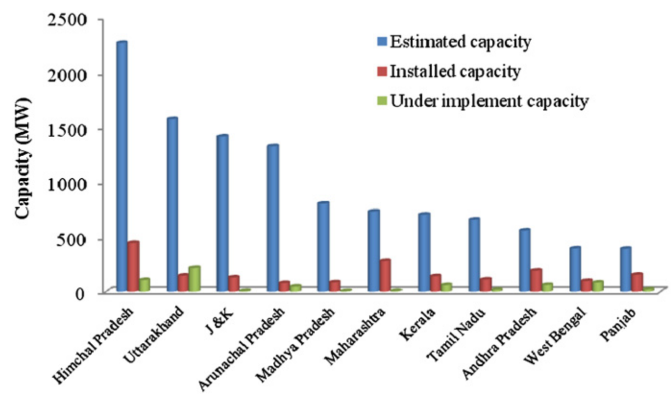

Fig. 8. Estimated, installed and under implementation capacity of SHP in various states.
Source: MNRE (2012).

Table 6
Private sector existing SHP projects in different states.

S. No.	State	Total number	Total capacity (MW)
1.	Andhra Pradesh	43	104.43
2.	Assam	1	0.10
3.	Gujarat	2	5.60
4.	Himachal Pradesh	63	271.25
5.	Haryana	2	7.40
6.	Jammu and Kashmir	2	17.50
7.	Karnataka	95	649.90
8.	Kerala	3	36.00
9.	Madhya Pradesh	1	2.20
10.	Maharashtra	13	74.00
11.	Orissa	2	32.00
12.	Punjab	18	26.20
13.	Tamil Nadu	1	0.35
14.	Uttaranchal	10	48.30
15.	West Bengal	5	6.45
Total		261	1326.68

5. Government initiatives to promote SHP in India

The Indian government has initiated several electricity policies in the last few years which have been talked about the need and priority to promote SHP as well as other renewable energy

sources in the country. Foremost amongst them is the Electricity Act 2003, National Electricity Policy 2005, National Tariff Policy 2006 and National Rural Electrification Policy 2006 have been addressed in numerous studies [41–51]. The directives released by Indian central government and different state governments to promote renewable energy are also discussed here in summarized manner as follows:

5.1. Electricity Act 2003

The enactment of the Electricity Act 2003 led to mandates promotion of renewable energy sources, co-generation, recognizes trading as a separate activity and it has ushered in a competitive era in the Indian power sector [41,42].

The some important points of Electricity Act-2003 regarding promotion of renewable in India are given as follows [46]:

- The State Electricity Regulatory Commissions shall be provided suitable measures to promote cogeneration and generation of electricity from RES by providing suitable measures for connectivity with the grid and sale of electricity to any person.
- The Appropriate Commission shall, subject to the provisions of this Act, specify the terms and conditions for the determination of tariff.

5.2. National Electricity Policy 2005

The National Electricity Policy 2005 stipulates that progressively the share of electricity from RES in terms of sustainable development would need to be increased; such purchase by distribution companies shall be through competitive bidding process [46]. Percentage for purchase of power from RES should be made applicable for the tariffs to be determined by the SERCs at the earliest [47].

5.3. The National Tariff Policy 2006

The distribution utilities can, however, seek competitive procurement of electricity generated from RESs as envisioned in the National Tariff Policy 2006 [45]. It mandates each SERC to specify a Renewable energy Purchase Obligation (RPO/RPS) by distribution licensees in a time-bound manner. This policy has the important provision for renewable promotion such as in pursuant to provisions of section 86 (1) (e) of the Electricity Act 2003, the appropriate commission shall fix a minimum percentage for purchase of energy from renewable sources taking into account availability of such resources in the region and its impact on retail tariffs. Such percentages for purchase of energy should be made applicable for the tariffs to be determined by the SERCs [46,48–49].

5.4. National Rural Electrification Policies (NREP), 2006

The NREP-2006 permitting stand-alone systems using RES has been notified by the Ministry of Power in 2006. This policy provides guidelines for setting up of such systems for off-grid systems in rural areas in the country, and specifies tariff forbearance for electricity supply to consumers in these areas and other regulatory dispensations applicable in this context [46,48,51].

5.5. State level initiatives

There are several state level policies which are independent and different from various national level policies are also promoting the SHP as the renewable power generation source [46,52]. The state level policies for SHP are well governed by various state electricity boards and respective agencies for renewable energy.

In India, 23 state governments have so far announced policy for private sector participation for the development of SHP projects. The SERCs have been deciding tariff in their respective states. These states are Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, Uttaranchal and West Bengal [53].

(a) Feed-in tariff policy for SHP: Feed-in tariffs are a generic description of a policy that pays a price, a "tariff", for the electricity generated by renewable sources of energy that is "fed" into or sold to the grid. As Feed-in tariff is place specific as well as source specific so in each of the electricity regulatory commission adopt different tariff for different renewable sources in India [44].
Though SHP projects in Himachal Pradesh, Uttarakhand, and the northeastern states have a higher capital cost, they also have higher capacity factors due to the hilly terrain and resource availability, so the tariffs offered in these states are less than those offered for projects in other states. Projects below 5 MW often have higher capital and operating costs and cannot take advantage of economies of scale. The tariff period for small hydro of less than 5 MW has been modified to run for 35 years in order to provide long-term certainty. The tariff period for small hydropower above 5 MW is normally 13 years. CERC has established preferential levellised tariffs for different states and plant capacities as FY 2012–2013 (refer Table 7) [52].

(b) Bay back for SHP: If you can generate electricity for your own home from renewable energy sources you can sell any excess renewable energy back to synergy. Customers on this scheme are billed for their net import and credited for their net export of electricity over a billing period. Residential customers are offered renewable energy buyback rates equal to their selected electricity purchase rates [44].
Changes to metering requirements may also be required to allow eligible customers, at multi-residential premises, to participate.

Table 7
Feed- in-tariff (Rs/kW h) for SHP Technology for FY 2012–2013 [52].
Source: CERC (2012).

State	Levellised total tariff	Benefit of accelerated depreciation (if availed)	Net-levellized tariff (after adjusting for accelerated benefit)
Himachal Pradesh, Uttarakhand and Northeastern States (Below 5 MW)	4.14 Rs./kW h (Tariff period 35 years)	0.32 Rs/kW h	3.82 Rs/kW h
Himachal Pradesh, Uttarakhand and Northeastern States (5 MW to 25 MW)	3.54 Rs/kW h (Tariff period 13 years)	0.29 Rs/kW h	3.25 Rs./kW h
Other States (Below 5 MW)	4.88 Rs/kW h (Tariff period 35 years)	0.38 Rs/kW h	4.50 Rs./kW h
Other States (5 MW to 25 MW)	4.16 Rs/kW h (Tariff period 13 years)	0.34 Rs/kW h	3.82 Rs/kW h

The scheme is also open to non-profit organizations and to educational institutions (schools, universities, etc.). However, as smart power is not available to these sectors, only the buyback rate equivalent to the applicable tariff rate is available. Bay-back rate provided by various SERCs are given in Table 8 [53].

5.6. Financial assistance schemes

The MNRE has been provided financial support/subsidy for following activities to develop the SHP sector as shown in Table 9 [54]. It is also recommended that the MNRE subsidy should be continued in the 12th five year Plan. In the current MNRE scheme, the subsidy for incremental MWs is extremely low. This should be increased to Rs.1.0 crore/MW for government sector projects and Rs. 50 lakh/MW for private sector projects. MNRE is also providing central financial assistance to set up small and micro hydro projects in public as well as private sectors. This financial support has also given to the state government for identification of new SHP potential sites including survey, preparation of detail project reports, renovation as well as modernization of old SHP projects.

The Indian Renewable Energy Development Agency (IREDA) is the financial institution that also provides the loans for setting up SHP projects. A special incentive package has been developed for the promotion of the SHP programme in the North-Eastern states (Sikkim, J&K, Himachal Pradesh and Uttaranchal), giving capital grants per MW [55].

Table 8
Bay back rate in Rs/kW h in India for SHP [53].

S. No.	State	Bay back rate
1.	Andhra Pradesh	2.69 (04–05)
2.	Haryana	2.25 (94–95)
3.	Himachal Pradesh	2.50
4.	Karnataka	2.90
5.	Kerala	2.25
6.	Madhya Pradesh	2.25 (99–00)
7.	Punjab	2.73 (98–99)
8.	Rajasthan	2.75 (98–99)
9.	Uttar Pradesh	2.25
10.	West Bengal	2.25

6. Priority of SHP in India

SHP is the most promising and economically viable form of comparison to other renewable energy technology in India, with an average economic cost of approx Rs 3.90/kW h. SHP can be provided economical solution for the energy problems in basically off-grid, remote, rural and hilly area in India, where extension of grid system is comparatively uneconomical and also along the canal system having sufficient drops [56–60]. SHP has a capital cost of about 60–70 (FY 2012–2013) million rupees/MW in India, which is the lowest among renewable energy technologies in India [52].

SHP are high efficiency of between 70 and 90%, by far the best of all renewable energy technologies and high capacity factor of about 50%, compared with 10% for solar and 30% for wind [61]. It is a long-lasting and robust technology; systems can readily be engineered to last for 50 years or more and therefore an attractive energy pay-back ratio even for developing countries like India.

SHP continues to be the most efficient, reliable, clean, and largely carbon-free, and represents a flexible peak-load technology way to generate electricity. It is also produces negligible amounts of greenhouse gases and lifespan up to 100 years and therefore an attractive energy pay-back ratio even for developing countries. So, there is growing interest for the development of substantial SHP potential in India [62–65]. Therefore, Government of India in point of electricity demand as well as more RES utilization of SHP plants offers a practical solution to the issues of inadequate, poor and unreliable power supply [60].

7. Water quality problems and mitigations

The presence of high silt content in rivers, particularly during peak snow melt and high flows, present an engineering challenge during operation of SHP plants [66]. The operations of SHP may also change water temperatures, and lower the levels of dissolved oxygen [67,68]. The erosion of hydro turbine components is a major problem for the efficient operation of these plants. Theoretical studies were made to discuss the main causes of damage of water turbines viz. cavitations problems, sand erosion, material defects and fatigue. Based on the available studies it was found that the best efficiency point of turbine decreased in direct proportion to the increase in silt concentration [69].

Table 9
Financial assistance schemes for SHP by MNRE.
Source: MNRE (2012).

	Category	Above 100 kW and up to 1000 kW	Above 1–25 MW
(i) Support to new SHP projects in state sector	Special category and NE States	Rs. 50,000/kW	Rs. 5.00 crore for first MW+Rs. 50 lakh/MW for each additional MW
	Other States	Rs. 25,000/kW	Rs. 2.50 crore for first MW+Rs. 40 lakh/MW for each additional MW
	• Minimum of 10% contribution of the project cost from the implementing organization. • The subsidy would be released in four installments based on progress in the project.		
(ii) Support to new SHP projects in private/co-operative/joint sector	Special category and NE states	Rs. 20,000/kW	Rs. 2.00 crore for first MW+Rs. 30 lakh/MW for each additional MW
	Other states	Rs. 12,000/kW	Rs. 1.20 crore for first MW+Rs. 20 lakh/MW for each additional MW
	• Minimum of 50% contribution of the project cost from the project developer/owner of the project. • The subsidy would be released in two installments. 50% subsidy will to be released to the financial institution, during execution of the project (after placement of order for electro-mechanical equipment and 50% loan disbursement) and balance after performance testing.		
(iii) Scheme to support Renovation and modernization of old SHP projects in public sector	Special category	Rs. 25,000/kW	Rs. 2.50 crore for and NE States first MW+Rs. 50 lakh/MW for each additional MW
	Other states	Rs. 15,000/kW	Rs. 1.50 crore for first MW+ Rs. 35 lakh/MW for each additional MW
	• Minimum of 50% contribution of the project cost from the State sector project implementing organization of the works. • The subsidy would be released in three installments based on progress in the project.		

The environmental consequences of hydropower are related to encroachments upon nature due to damming or lowering of the water level, changed water flow and building of roads and power lines. Hydropower Project reservoirs have a deleterious effect on downstream water quality of the rivers in India. The most apparent problem is the blue–green algae blooms, which develop in these slowed, warmed waters and, following their release from the reservoirs, create degraded conditions downstream [70,71]. High silt levels have forced the shutdown of several small hydropower plants in India. These plants are experiencing excessive silt levels due to heavy rainfalls in catchment areas [72].

Presently, GOI takes some major initiatives to mitigate the water quality related problems. The run-of-river hydropower plants are regularly using to improve oxygen levels and filter tones of floating waste out of the river, or to reduce high water temperature levels from thermal power generating outlets. However, maintaining the water quality of reservoirs is often a challenge, as reservoirs constitute a focal point for the river basin catchment. Water quality issues related to reservoirs depend on several factors: climate, reservoir morphology and depth, water retention time in the reservoir, water quality of tributaries, quantity and composition of the inundated soil and vegetation, and rapidity of impounding [73,74].

8. Environmental benefits of SHP

SHP is considered to be a clean, renewable source of energy, emitting a very low level of greenhouse gases when compared to fossil fuels. It has a low operating cost once installed and can be highly automated. An additional benefit is that the power is generally available on demand since the flow of water can be controlled.

One of the largest environmental benefits of SHP is that there is no carbon dioxide produced during electricity generation. SHP does not require fossil fuels and does not emit greenhouse gases associated with the burning of fossil fuels. As such, in these terms, it is one of the most environmentally-friendly methods of electricity generation. Another environmental advantage of SHP is that water is not polluted during the process and can be utilized for additional processes, such as crops or water supplies [75].

On average, every 1 GW of additional renewable energy capacity reduces CO_2 emissions by 3.3 million tons a year. So there is a great need to promote the SHP in Indian power sector to meet future energy demand and remove GHG emission for environment protection. The National action plan on climate change 2008 aims to reduce carbon intensity by 20–25% by 2020 (compared with 2005 levels). It suggested that as much as 15% of India's energy could come from renewable sources by 2020 [46,76].

9. Clean development mechanism (CDM) of hydro and SHP projects

SHP projects could be of interest under the CDM because they directly displace greenhouse gas emissions while contributing to sustainable rural development [77]. CDM has certainly brought renewable energy into the main foray of world's focus on sustainable development. The key feature of this mechanism is that the developed world gets to realize its emission reduction targets and the developing world to benefit from the clean energy technology implementation. The CDM projects implementation results in carbon emission reductions commonly known as CER's which today have a huge market. Hydropower projects have again emerged as one of the most popular projects to be developed into CDM project activity because of its environment benign nature [78]. India has a vast opportunity to explore in terms of CDM and carbon-credits, central government constituted the national clean development mechanism authority for the purpose of protecting and improving the quality of environment in terms of the Kyoto Protocol.

India is a favorable destination for CDM projects, with renewable energy projects having the major share, but due to stringent project based approval process and high transaction costs, CDM potential is not being realized fully. Programmatic CDM requires immediate reform. National renewable energy plans offer ample opportunity for CDM projects and technological innovations. MNRE has developed a framework for undertaking renewable energy projects under programmatic approach [79].

An analysis was undertaken for India with regard to hydropower and CDM. Fig. 9 presents the percentage of existing CDM projects in different states of India as on end of August 2012. It was found that 241 projects amounting to 13,267 MW were under various stages of approval at the CDM executive board [80].

10. Future goal of SHP

Alternate Hydro Energy Centre (AHEC) IIT, Roorkee is the leading technical centre for small hydro [81]. It has been providing professional support in the field of SHP development covering planning,

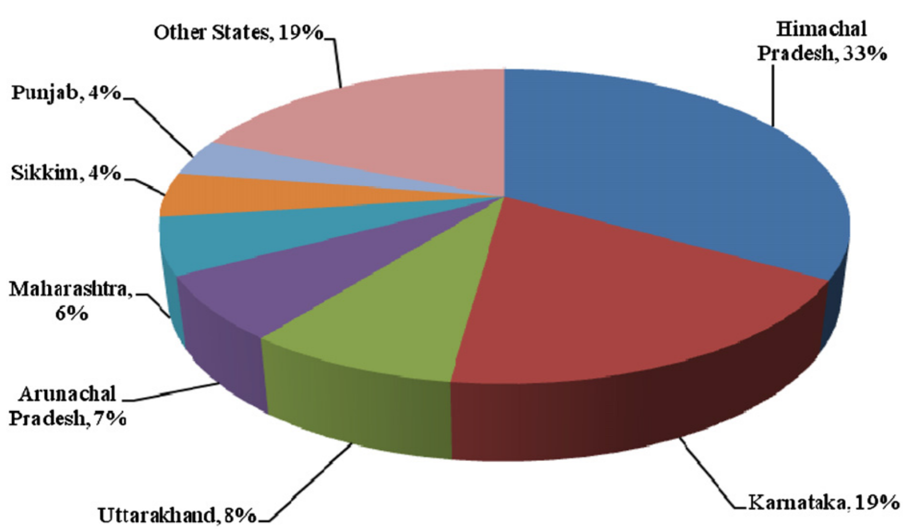

Fig. 9. CDM hydro and SHP project in India.
Source: www.cdmpipeline.org; (2012)

Table 10
Year-wise targets for grid interactive SHP capacity for the period 2011–2017.
Source: MNRE (2012).

Year	Capacity (MW)
Cumulative (up to 31.08.12)	3434.1
2012–2013	350
2013–2014	400
2014–2015	400
2015–2016	450
2016–2017	500
Total target for the5-year period	2100
Cumulative total target	5534.1

detailed project reports, detailed engineering designs and construction drawings, technical specialization of turnkey execution/equipment supply, renovation and modernization of SHP stations, and techno-economic appraisal [54].

The additional capacity of 2100 MW for SHP projects has been planned for the 12th five year plan (2012–2017) period in India. The India has an estimated SHP potential of about 15,384 MW out of which 898 projects with an aggregate capacity of 3434 MW have been set up and 348 projects aggregating to 1309 MW are under implementation [11]. The projected figure of 8500 MW of cumulative capacity of SHP projects by the end of the year 2021–2022 is at all to be believed, the total installed capacity would be about 55 per cent of the identified potential. This percentage may come down substantially as more potential sites may be identified by the year 2021–2022 i.e., the completion year of the 13th plan [54]. The year-wise targets for grid interactive SHP capacity (MW) for the period 2012–2017 as shown in Table 10 [11,82].

11. Conclusions

Government of India estimates, the power requirement in the country will increase to 400,000 MW by 2020. So, India needs to exploit all its available natural resources to the fullest in order to bridge the widening demand-supply gap in the power sector. The Indian government has set specific targets for renewable energy including SHP achievements by 2020. It is expected that renewable energy to contribute 15% of total power generation capacity by 2020. India has an assessed hydropower potential to the tune of 84,000 MW at 60% load factor; out of this only about 25% has been developed so far. Hydroelectric power plants generate only 20% of the total electricity consumed in the country whereas 67% of the total electricity being generated by thermal power plants which are highly polluting and depend on non-renewable fossil fuels.

Considering the large untapped potential and the intrinsic characteristics of SHP in promoting the country's energy security and flexibility in system operation, the Government is giving a thrust to accelerate SHP development. SHP development in India can also be an important tool for regional economic development, particularly for many underdeveloped states, which have the greatest potential for developing SHP, which is unlimited and clean source of energy. It can provide secure electricity supply to foster domestic industrial development. So it can be concluded that SHP development is of great importance from the point of view of long term energy supply security, decentralization of energy supply particularly for the benefit of the rural population, environmental benefits and sustainability in power sector also.

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